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⑤④ Ink jet recording sheet.

⑤⑦ An ink jet recording sheet, having high ink absorption, water resistance, persistency, a satisfactory fabric-like soft touch, mechanical strength and being capable of recording ink images having a high quality, includes an undercoat layer formed on a surface of a substrate sheet and comprising a resin material and an ink-receiving layer formed on the undercoat layer and comprising an ink-receiving resin and a pigment, the undercoat layer being formed by foaming a coating liquid including a resin material and coating the foamed coating liquid, having an apparent volume of 2 to 20 times that of the original (non-foamed) coating liquid and a viscosity of 4,000 to 300,000 cps as determined by a Brookfield type viscometer, onto the substrate sheet.

**EP 0 663 300 A1**

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

5 The present invention relates to an ink jet recording sheet. More particularly, the present invention relates to an ink jet recording sheet having high ink absorption, water resistance and mechanical strength, a satisfactory soft touch and persistency, a capability of recording clear ink images thereon and suitable for use for hand-writing to the same extent as fine paper sheets or coated paper sheets.

## 10 2. Description of Related Art

In the field of ink jet recording systems, particularly aqueous ink jet recording systems, the printing performances, for example, printing speed, resolving power and chroma are currently significantly developing. Due to the development of the recording systems, the field of use of ink jet recording systems is expanding. However, with respect to the recording material, further enhanced performance is required. Especially, a coated recording sheet having an ink-receiving layer formed on a substrate sheet is developed for the purpose of improving the ink absorption speed and controlling the amount and regulated of the ink.

For example, Japanese Unexamined Patent Publication (Kokai) No. 62-158084 discloses a process for producing an aqueous ink jet recording sheet having an ink-receiving layer comprising fine synthetic silica particles dispersed on a binder resin matrix, and thus exhibiting an enhanced ink absorption, an improved color-reproduction property and a high color density. Namely, it is known that a resinous coating layer comprising a white pigment, for example, fine synthetic silica particles having a high ink absorption, is formed on a surface of a substrate sheet comprising, as a principal component, a cellulose pulp.

Also, due to the expansion of the field in which ink jet recording systems are used, ink jet-recording systems have become widely used in office documentation and for advertisements, especially, purchase-offering advertisements, due to the advantage that in the ink jet recording, no printing plate is necessary and thus a small number of printed sheets can be easily produced, and the recording or printing cost is low.

Nevertheless, the conventional ink jet recording sheet is disadvantageous in that since the substrate sheet consists of a natural pulp paper sheet, the resultant recording sheet exhibits a poor water resistance and a poor wet mechanical strength. Even if a water-resistant substrate sheet is used, the resultant conventional recording sheets have problems of expansion, wrinkling and curling when wetted with water, and thus are not suitable for outdoor use. As an attempt to eliminate the above-mentioned disadvantages, Japanese Unexamined Patent Publication (Kokai) No. 64-36478 discloses an ink jet recording sheet comprising a substrate sheet consisting of a film comprising, as a principal component, a polyolefin resin, and a hydrophobic ink-receiving-fixing layer formed on the film. This ink jet recording sheet has an enhanced water resistance, and is usable for point of purchase (POP) advertisements. However, when the polyolefin resin film is utilized, the resultant substrate sheet has no ink absorption, and thus to restrict the spreading of the ink on the surface of the recording sheet and to impart a proper ink absorption to the recording sheet, it is necessary that the ink-receiving layer is formed in a large thickness thereof. Also, this type of ink jet recording sheet is disadvantageous in that the opaqueness and flexibility thereof are unsatisfactory.

Currently, various types of nonwoven fabrics have been developed and become useful in various field. A nonwoven fabric is prepared by accumulating a plurality of fibers (staple fibers or filaments (continuous filaments) to form a web and subjecting the web to a process in which the fibers or filaments are partially bonded with each other or intertwined with each other. The intertwining can be effected by a wet method or a dry method. The filaments can be converted to a nonwoven fabric by a spun-bonding method, or a melt-blowing method. The properties of the nonwoven fabric are variable depending on the type of production methods thereof. Generally, the nonwoven fabric has relatively high tear strength, burst strength and tensile strength, a high water resistance and a preferred hand feeling and flexibility.

To solve the problems of the conventional ink jet recording sheets such that the water resistance, opaqueness and flexibility thereof are unsatisfactory, attempts have been made to utilize the above-mentioned nonwoven fabrics, or woven fabrics, as a substrate sheet.

However, the utilization of the nonwoven fabric is disadvantageous in that when a coating liquid for the ink-receiving layer is applied to the nonwoven fabric which is porous and allows the coating liquid to easily penetrate into the nonwoven fabric, the nonwoven fabric is entirely impregnated with the coating liquid, and thus it is difficult to form a smooth ink-receiving surface. Also, the nonwoven fabric causes the coating liquid to be consumed in an excessively large amount and the resultant ink jet recording sheet exhibits an unsatisfactory stiffness and opaqueness.

An object of the present invention is to provide an ink jet recording sheet having not only high tensile

strength, tear strength, water resistance and persistency and a satisfactory flexibility and hand feeling, but also an excellent ink absorption and ink-dotted image reproducibility.

Another object of the present invention is to provide an ink jet recording sheet useful for recording clear ink images thereon by using an ink jet recording printer or a plotter at high speed.

## SUMMARY OF THE INVENTION

The above-mentioned objects can be realized by the ink jet recording sheet of the present invention which comprises a substrate sheet; an undercoat layer formed on the substrate sheet and comprising a foamed resin material; and an ink-receiving layer formed on the foamed undercoat layer and comprising a mixture of an ink-receiving resin material and a pigment. This ink-receiving layer is a non-foamed resinous layer.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the ink jet recording sheet of the present invention, it is important that the ink-receiving layer is located on a foamed undercoat layer.

The foamed undercoat layer is formed on a substrate sheet by coating a substrate sheet surface with a foamed resin material-coating liquid. Although this foamed resin material-coating liquid has a relatively high viscosity, it can be smoothly coated on the substrate sheet surface without excessively penetrating into the substrate sheet, and forms a barrier to a coating liquid for the ink-receiving layer. When the foamed undercoat layer is solidified on the substrate sheet, the resultant layer serves as a barrier to prevent the penetration of a coating liquid for the ink-receiving layer into the substrate sheet.

The substrate sheet usable for the present invention is selected from nonwoven fabrics and woven fabrics.

The nonwoven fabrics may be produced by conventional nonwoven fabric-forming methods, for example, a spun-bonding method, wet laid nonwoven fabric-forming methods, staple fiber-carding method, hydroentanglement method, and air laying method.

Preferably, the substrate sheet for the ink jet recording sheet of the present invention is a spun-bonded filament sheet produced by accumulating spun continuous filaments to form a web and partially fuse-bonding the filaments of the web to each other. The partial fuse-bonding is carried out by heat-pressing the filament web between a pair of heat-pressing rolls having roughened surfaces, or between a surface-roughened roll and a smooth surface roll, so that the filaments are brought into contact with protruding parts of the surface-roughened roll and partly fuse-bonded to each other. Alternatively, the web is introduced between a surface-roughened roll and an ultrasonic horn and an ultrasonic treatment is applied to the web. In this ultrasonic treatment, the portions of the filaments brought into contact with the protruding parts of the roll are partially fuse-bonded to each other.

In the spun-bonded nonwoven fabric, the fuse-bonded portions serve to enhance the mechanical strength and dimensional stability of the nonwoven fabric, and the non-fuse-bonded portions impart an appropriate flexibility and hand feeling to the nonwoven fabric.

The continuous filament comprises a member selected from, for example, polyethylene, polypropylene, polyester, polyacrylate and polyamide homopolymer and copolymer resins.

The above-mentioned synthetic filaments may be employed alone or in a blend of two or more different types of filaments.

The substrate sheet usable for the present invention may be produced by staple fiber-carding method in which staple fibers are opened and accumulated into the form of a web by a carding machine, and the staple fibers in the web are partially bonded to each other by heat-fusing or through a binder resin or binder fibers. The staple fibers are preferably selected from polyolefin fibers, polyester fibers, polyamide fibers, rayon fibers and cotton fibers. These fibers may be employed alone or in a blend of two or more types of the fibers.

The staple fibers preferably have a length of 20 to 200 mm, more preferably 30 to 150 mm. If the fiber length is less than 20 mm, the resultant nonwoven fabric produced by the staple fiber-carding method has unsatisfactory mechanical strength and flexibility. Also, if the fiber length is more than 200 mm, it becomes difficult to open the staple fibers using a carding machine, the resultant nonwoven fabric has a poor quality.

The nonwoven fabric usable for the present invention may be produced by a wet laid nonwoven fabric-forming method in which a plurality of staple fibers dispersed in an aqueous liquid are formed into a sheet.

The nonwoven fabric usable for the present invention may be produced by a hydro-entanglement method in which the staple fiber web prepared the carding machine is subjected to a high pressure water jet treatment. In this treatment, the staple fibers are intertwined by action of a plurality of high pressure water jets. In this type of nonwoven fabric, the staple fibers can be selected from the above-mentioned staple fibers.

The substrate sheet usable for the present invention optionally has a multi-layered structure in which a

plurality of fiber or filament sheets are laminated onto each other.

For example, a staple fiber web and a continuous filament web are laminated on each other, and a high pressure water jet treatment is applied to the laminate so that the staple fibers and the filaments are intertwined with each other to produce a spun lace nonwoven fabric. Preferably, this spun lace nonwoven fabric has a basis weight of 20 to 150 g/m<sup>2</sup>.

In the ink jet recording sheet of the present invention, the substrate sheet may comprise a woven fabric having a basis weight of 20 to 150 g/m<sup>2</sup>. The woven fabric may comprise at least one type of fibers or filaments of cotton, rayon, polyester, polyamide, and polyacrylic polymers.

Preferably, the substrate sheet has a thickness of 400  $\mu$ m or less. If the thickness is more than 400  $\mu$ m the resultant recording sheet may exhibit too poor a flexibility and thus cannot travel smoothly through a printer.

Where substrate sheet consists of a nonwoven fabric, it preferably has a basis weight of 20 to 150 g/m<sup>2</sup>, more preferably 30 to 100 g/m<sup>2</sup>. If the basis weight is less than 20 g/m<sup>2</sup>, the resultant substrate sheet exhibits an unsatisfactory opaqueness and a poor handling property. Also, if the basis weight is more than 150 g/m<sup>2</sup> the resultant substrate sheet may have too low a flexibility.

Also, the continuous filaments for the spun-bonded filament nonwoven fabric preferably have a thickness of 10/9 to 100/9 dtex (1 to 10 denier), more preferably 10/9 to 70/9 dtex (1 to 7 denier). If the thickness is less than 10/9 dtex (1 denier), it may become difficult to produce a filament sheet with a satisfactory stability in the sheet-forming procedure. Also, if the thickness is more than 100/9 dtex (10 denier) the resultant filament sheet may exhibit too low a flexibility due to the thickness of the filaments.

In the production of the ink jet-recording sheet, a surface of the substrate sheet is coated with a coating liquid for the undercoat layer and then with a coating liquid for the ink-receiving layer.

The undercoat layer-coating liquid comprises a foamed resin material alone or a mixture of a foamed resin material and a pigment, usually a white pigment. When the pigment is used, the mixing ratio of the weight of the pigment to the weight of the resin material is preferably 95 or less:5 or more, more preferably 40:60 to 90:10. If the content of the resin material (binder) is less than 5% by weight, the bonding strength between the substrate sheet and the undercoat layer may be unsatisfactory.

The resin material for the undercoat layer comprises at least one member selected from conventional binder resins, for example, homopolymers and copolymers of acrylic acid esters and methacrylic acid esters, ethylene-vinyl acetate copolymers, styrene-butadiene copolymers (SBR), acrylonitrile-butadiene copolymers (NBR), methyl methacrylate-butadiene copolymers (MBR), polyester resins and polyurethane resins. These resins are used in the state of a latex or aqueous emulsion. The above-mentioned resins may be mixed with at least one water-soluble polymer, for example, starch, starch derivatives, polyvinyl alcohol (PVA), casein, and carboxymethyl cellulose (CMC).

The pigments, especially white pigments usable for the undercoat layer are selected from inorganic pigments, for example, calcium carbonate, magnesium carbonate, magnesium hydroxide, aluminium hydroxide, zinc hydroxide, zinc oxide, titanium dioxide, aluminium oxide, silicon dioxide, amorphous silica, barium sulfate, kaolin and talc; and organic pigments, for example, styrene polymer and copolymer resins and acrylic acid ester polymer and copolymer resins. The most preferable pigment consists of fine amorphous silica particles.

The undercoat layer optionally contains an additive comprising at least one member selected from lubricants, antioxidants, ultraviolet ray-absorbing agents, colored pigments, antistatics and thickeners.

The undercoat layer can be formed by foaming a coating liquid comprising a resin material or a mixture of a resin material with a pigment by using a conventional foaming apparatus, for example, continuous foaming machine, shaking mixer or cake mixer, made by, for example, Gaston Country Co., U.S.A. or Stoke Co., Netherlands, and coating the foamed coating liquid on a surface of the substrate sheet.

The foaming operation is carried out preferably to such an extent that the volume of the coating liquid increases to 2 to 20 times that of the non-foamed coating liquid. If the foaming degree is too low, the resultant foamed coating liquid has a low viscosity and thus easily penetrate into the substrate sheet. Also, if the foaming degree is too high, the resultant foam has too large a size and thus the resultant undercoat layer has an unsatisfactory mechanical strength.

The foamed coating liquid preferably has a viscosity of 4,000 to 300,000 cps, more preferably 8,000 to 100,000 cps, measured by Brookfield type viscometer.

If the viscosity is less than 4,000 cps, even when the degree of foaming is appropriate, the resultant foamed coating liquid may undesirably penetrate into the substrate sheet and permeate to the opposite surface of the substrate sheet. If the viscosity is more than 300,000 cps, it becomes difficult to smoothly coat the foamed coating liquid.

Optionally, the coating liquid for the undercoat layer contains a foam stabilizer comprising at least one member selected from higher fatty acids, modified higher fatty acids and alkali metal salts of higher fatty acids. The foam stabilizer is preferably contained in an amount of 30 parts by weight or less, more preferably 1 to 10

parts by weight, per 100 parts by weight of the solid content of the coating liquid. If the foam stabilizer is used in an amount of more than 30 parts by weight, the resultant coating liquid may exhibit an unsatisfactory storage stability.

The coating operation for the undercoat layer can be carried out by using a conventional coating system, for example, a meyer bar, air knife, blade, slit die, lip, comma, roll, gravure, and rotary screen coating systems.

The undercoat layer is preferably formed at a dry solid weight of 5 to 50 g/m<sup>2</sup>, more preferably 4 to 30 g/m<sup>2</sup>. If the dry solid weight is less than 3 g/m<sup>2</sup>, the resultant undercoat layer may not serve as a satisfactory barrier layer for a coating liquid for the uppercoat layer, and thus the coating liquid penetrates into the substrate sheet therethrough. Also, if the dry solid weight is more than 50 g/m<sup>2</sup>, the resultant ink jet recording sheet sometimes exhibits too low a flexibility. After the coating liquid is applied, the resultant coating liquid layer on the substrate sheet is dried to form an undercoat layer.

Then, the surface of the undercoat layer is coated by a non-foamed ink-receiving layer comprising an ink-receiving resin material and a pigment, especially white pigment, to provide an ink-receiving layer.

In the ink-receiving layer, the pigment is preferably porous, exhibits a high ink absorption and enables the printed ink images to be clear and to have a brilliant color. Namely, the pigment preferably has a high oil absorption, a high specific surface area and a secondary particle size of 1 to 10  $\mu$ m.

The pigment for the ink-receiving layer most preferably consists of fine amorphous silica particles.

In the ink-receiving layer, the pigment content is preferably 50 to 90% by weight. If the content is less than 50% by weight, the resultant ink-receiving layer may exhibit unsatisfactory ink absorption. Also, if the content is more than 90% by weight, the resultant ink-receiving layer has unsatisfactory mechanical strength.

When fine amorphous silica particles are employed for the ink-receiving layer, the silica particles may be used together with another pigment, for example, zeolite, calcium carbonate, calcium silicate, aluminium hydroxide, anhydrous clay, kaolin clay, talc, white carbon and organic pigments (plastic pigments) which are all usable for coating paper sheets.

The resin material (binder) for the ink-receiving layer comprises at least one member selected from water-soluble polymeric materials, for example, polyvinyl alcohol, its water-soluble derivatives, proteins, for example, casein, starch and its derivatives; and water-insoluble polymeric materials in the form of a latex or aqueous emulsion, for example, conjugated diene polymers, for example, styrene-butadiene copolymers, and methyl methacrylate-butadiene copolymers, homopolymers and copolymers of acrylic acid esters and methacrylic acid esters, homopolymers and copolymers of vinyl compounds, for example, ethylene-vinyl acetate copolymers, modification products of the above-mentioned polymers and copolymers, which products have functional groups, for example, carboxyl group and cationic groups, thermosetting resins, for example, melamine-formaldehyde resins and urea-formaldehyde resins, which are available as aqueous adhesive, anhydrous malleic acid copolymer resins, polyacrylamide adhesives, polymethylmethacrylate adhesives, polyurethane adhesives, unsaturated polyester adhesives, polyvinylbutyral adhesives and alkyd resin adhesives. These resin materials have a satisfactory binding property for the pigment and a high affinity to aqueous ink and thus exhibit good ink absorption.

In the ink-receiving layer, the dry solid content of the resin material is preferably 10 to 50% by weight, more preferably 10 to 40% by weight, based on the total dry solid weight of the ink-receiving layer. If this content is less than 10% by weight, the resultant ink-receiving layer sometimes exhibits unsatisfactory mechanical strength. When the content is more than 50%, the pigment particles are satisfactorily bonded and the resultant ink-receiving layer is firmly bonded to the undercoat layer but the resultant ink-receiving layer sometimes exhibits poor ink absorption due to the reduced content of the pigment.

The ink-receiving layer can be formed by the same coating method as those of the undercoat layer except that the resin-pigment mixture is not foamed. The amount of the ink-receiving layer is varied depending on the use of the recording sheet and required ink absorption, recording performance, storage durability and opaqueness. Preferably, the ink-receiving layer is formed with a dry solid weight of 3 to 30 g/m<sup>2</sup>. If the dry solid weight is less than 3 g/m<sup>2</sup> the resultant ink-receiving layer may exhibit an unsatisfactory ink absorption thus the printed ink is undesirably spread, the color is spread out and the printed ink images become unclear. Also, the non-absorbed portion of the printed ink does not dry quickly and stains the guide rolls in a printer. However, if the dry solid weight is more than 30 g/m<sup>2</sup>, sometimes the resultant thick ink-receiving layer cannot be firmly bonded to the undercoat layer, which can cause an ink jet nozzle in a printer to be blocked by dust generated from the undercoat layer, and has a high cost.

The resultant ink jet recording sheet is optionally surface-smoothed by a super calender or machine calender to enhance the printing performance of the surface.

The calendering treatment is preferably applied under a linear pressure of 70 kg/cm or less, more preferably 50 kg/cm or less. If the linear pressure is more than 70 kg/cm, the resultant formed ink-receiving layer exhibits too high a density, and the resultant ink jet recording sheet exhibits too high a stiffness. In the calendering

treatment, a heating calender roll is optionally used. In this case, a satisfactory surface-smoothing effect can be obtained under a lower linear pressure than can be obtained by using a non-heating calender roll.

## EXAMPLES

The present invention will be further explained by the following specific examples which are merely representative and do not limit the scope of the present invention in any way.

### Example 1

A spun-bonded filament nonwoven fabric was prepared by melt-spinning a polyethylene terephthalate resin at a temperature of 280°C, accumulating the melt-spun filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 230°C. The filaments in the resultant nonwoven fabric had a thickness of 3.3 dtex (3.0 denier) and the nonwoven fabric had a basis weight of 50 g/m<sup>2</sup>.

Separately, a coating liquid (1) for an undercoat layer was prepared by mixing 100 parts by weight of a polyurethane emulsion (trademark: Polyurethane HW 940, made by Dainihon Ink, dry solid content: 50% by weight) with 5 parts by weight of a foam stabilizer (trademark: F-1, made by Dainihon Ink) and foaming the mixture by a hand mixer to such an extent that the apparent volume of the coating liquid increased to 6 times the non-foamed coating liquid volume.

The foamed coating liquid (1) had a viscosity of 30,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (1) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 13 g/m<sup>2</sup>.

Separately, a coating liquid (2) for an ink-receiving layer was prepared by mixing 100 parts by weight of fine silicate particles (trademark: Finesseal, made by Tokuyama Soda K.K.) with 30 parts by weight of polyvinyl alcohol (trademark: PVA 117, made by Kuraray).

The coating liquid (2) was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 10 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

### Example 2

An ink jet recording sheet was produced using the same procedures as in Example 1 with the following exceptions.

A spun-bonded filament nonwoven fabric was prepared by melt-spinning a polyethylene terephthalate resin at a temperature of 280°C, accumulating the melt-spun filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 230°C. The filaments in the resultant nonwoven fabric had a thickness of 2.78 dtex (2.5 denier) and the nonwoven fabric had a basis weight of 100 g/m<sup>2</sup>.

Separately, a coating liquid (3) for an undercoat layer was prepared by mixing 100 parts by weight of a polyacrylic resin emulsion (trademark: AE513A, made by Nihon Goseigomu, dry solid content: 44% by weight) with 7 parts by weight of a foam stabilizer (trademark: SN Foam 200, made by Sunnopco) and foaming the mixture by a hand mixer to such an extent that the apparent volume of the coating liquid increased to 10 times the non-foamed coating liquid volume.

The foamed coating liquid (3) had a viscosity of 25,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (3) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 8 g/m<sup>2</sup>.

The same coating liquid (2) as in Example 1 was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 15 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

### Example 3

An ink jet recording sheet was produced using the same procedures as in Example 1 with the following exceptions.

A spun-bonded filament nonwoven fabric was prepared by melt-spinning a polyethylene terephthalate resin at a temperature of 280°C, accumulating the melt-spun filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 230°C. The filaments



in the resultant nonwoven fabric had a thickness of 2.78 dtex (2.5 denier) and the nonwoven fabric had a basis weight of 30 g/m<sup>2</sup>.

Separately, a coating liquid (4) for an undercoat layer was prepared by mixing 100 parts by weight of an SBR latex (trademark: Latex 0629, made by Nihon Goseigomu, dry solid content: 46% by weight) with 10 parts by weight of titanium dioxide (trademark: JA-1, made by Teikoku Kako) and 5 parts by weight of a foam stabilizer (trademark: F-1, made by Dainihon Ink) and foaming the mixture by a hand mixer to such an extent that the apparent volume of the coating liquid increased to 6 times the non-foamed coating liquid volume.

The foamed coating liquid (4) had a viscosity of 28,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (4) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 10 g/m<sup>2</sup>.

Separately, a coating liquid (5) for an ink-receiving layer was prepared by mixing 100 parts by weight of fine silicate particles (trademark: Fineseal, made by Tokuyama Soda K.K.) with 20 parts by weight of SBR latex (trademark: 0613, made by Nihon Goseigomu).

The coating liquid (5) was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 12 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### Example 4

An ink jet recording sheet was produced using the same procedures as in Example 1 with the following exceptions.

A spun-bonded filament nonwoven fabric was prepared by melt-spinning a polypropylene resin at a temperature of 230°C, accumulating the melt-spun filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 140°C. The filaments in the resultant nonwoven fabric had a thickness of 2.2 dtex (2.0 denier) and the nonwoven fabric had a basis weight of 60 g/m<sup>2</sup>.

Separately, a coating liquid (6) for an undercoat layer was prepared by mixing 100 parts by weight of a polyvinyl acetate emulsion (trademark: Boncoat 2830, made by Dainihon Ink, dry solid content: 50% by weight) with 10 parts by weight of a foam stabilizer (trademark: F-1, made by Dainihon Ink) and foaming the mixture by a hand mixer to such an extent that the apparent volume of the coating liquid increased to 8 times the non-foamed coating liquid volume.

The foamed coating liquid (6) had a viscosity of 32,000 cps as measured by a Brookfield type viscosity.

The foamed coating liquid (6) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 5 g/m<sup>2</sup>.

The same coating liquid (5) as in Example 3 was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 20 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### Example 5

An ink jet recording sheet was produced by the same procedures as in Example 1 with the following exceptions.

A coating liquid (7) for an undercoat layer was prepared by mixing 100 parts by weight of a polyacrylic resin emulsion (trademark: Boncoat 3226, made by Dainihon Ink, dry solid content: 45% by weight) with 6 parts by weight of a foam stabilizer (trademark: SN Foam 200, made by Sunnopco) and foaming the mixture by a hand mixer to such an extent that the apparent volume of the coating liquid increased to 6 times the non-foamed coating liquid volume.

The foamed coating liquid (7) had a viscosity of 25,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (7) was coated on a surface of the same nonwoven fabric as in Example 1, using a Meyer bar coater, and dried. The resultant foamed undercoat layer had a dry solid weight of 20 g/m<sup>2</sup>.

Separately, a coating liquid (8) for an ink-receiving layer was prepared by mixing 100 parts by weight of fine silicate particles (trademark: Fineseal, made by Tokuyama Soda K.K.) with 7 parts by weight of a modified polyvinyl alcohol (trademark: Gosefimer, made by Nihon Goseikagaku) and 10 parts by weight of an SBR latex (trademark: 0613, made by Nihon Goseigomu).

The coating liquid (8) was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 5 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

Comparative Example 1

An ink jet recording sheet was produced by the same procedures as in Example 1 except that the foamed undercoat layer was omitted and the non-foamed ink-receiving layer had a dry solid weight of 23 g/m<sup>2</sup>.

Comparative Example 2

An ink jet recording sheet was produced by the same procedures as in Comparative Example 1 except that the foamed undercoat layer had a dry weight of 2 g/m<sup>2</sup>.

Comparative Example 3

An ink jet recording sheet was produced by the same procedures as in Example 5 except that the non-woven fabric was replaced by a synthetic paper sheet (trademark: Yupo FPG 60, made by Oji Yuka Goseishi, thickness: 60  $\mu$ m), and the foamed undercoat layer was omitted.

In the above-mentioned examples and comparative examples, the resultant ink jet recording sheets were subjected to the following tests.

(1) Permeability of coating liquid for forming an ink-receiving uppercoat layer through the substrate sheet.

The permeability of the coating liquid for the ink-receiving layer through a substrate sheet or a laminate of a substrate sheet and an undercoat layer formed on the substrate sheet was observed by the naked eye, and the resistance to the permeation of the coating liquid was evaluated into the following classes.

Class	Permeability
3	No coating liquid permeated to the back surface of the substrate sheet.
2	A small amount of the coating liquid permeated to the back surface of the substrate sheet.
1	A large amount of the coating liquid permeated to the back surface of the substrate sheet.

(2) Ink absorption

An ink jet recording sheet was ink-printed by an ink jet printer (DESK WRITER, made by Hewlett Packard), and the time, in seconds, necessary to complete the drying of the printed ink was measured. The necessary drying time was classified into the following three classes.

Class	Ink absorption (Drying time (sec))
3	3 seconds or less
2	4 to 10 seconds
1	11 seconds or more

(3) Color brightness

By using an ink jet printer (DESK WRITER-C, made by Hewlett Packard), yellow, magenta and cyan inks were printed. The printed colored images in each color were observed by the naked eye and evaluated into the following classes.

Class	Color brightness
3	Bright
2	Slightly unsatisfactory
1	Bad

(4) Dot reproducibility

The ink dots printed by the ink jet printer (DESK WRITER, made by Hewlett Packard) was observed through a microscope, and evaluated into the following classes.

Class	Form of printed dots
3	Substantially complete circle
2	Slightly deformed circle
1	Clearly deformed circle

## (5) Tear strength

The tear strength of an ink jet recording sheet was determined in accordance with Japanese Industrial Standard (JIS) P 8116.

## (6) Water resistance

The ink jet recording sheet was immersed in water at a temperature of 20°C for one hour, and the separation of the coated layers and the substrate sheet from each other, the wrinkling of the sheet after drying and the breakage of the sheet were observed by naked eye. The water resistance of the recording sheet was evaluated into the following classes.

Class	Water resistance
3	Substantially no change occurred.
2	Slight changes occurred.
1	Significant changes occurred.

The test results are shown in Table 1.

Table 1

Item Example No.	Resistance to permeation of coating liquid	Color bright- ness	Ink absorp- tion	Dot- repro- duci- bility	Tear strength (g)		Water resist- ance
					Longi- tudinal	Trans- versal	
Example	1	3	3	3	480	500	3
	2	3	3	3	1250	540	3
	3	3	3	3	160	380	3
	4	3	3	3	600	505	3
	5	3	3	3	480	500	3
Compar- ative Example	1	1	3	3	480	500	3
	2	1	3	3	1250	540	3
	3	3	3	2	18	7	3

Example 6

A spun-bonded filament nonwoven fabric was prepared by accumulating a plurality of continuous polyethylene terephthalate filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 230°C. The filaments in the resultant nonwoven fabric had a thickness of 3.0 dtex (2.7 denier) and the nonwoven fabric had a thickness of 250 µm.

Separately, a coating liquid (10) for an undercoat layer was prepared by mixing 100 parts by weight of a polyurethane emulsion (trademark: Polyurethane HW 940, made by Dainihon Ink, dry solid content: 50% by weight) with 10 parts by weight of a foam stabilizer (trademark: F-1, made by Dainihon Ink) and foaming the mixture using a hand mixer to such an extent that the apparent volume of the coating liquid increased to 8 times the non-foamed coating liquid volume.

The foamed coating liquid (10) had a viscosity of 33,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (10) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 10 g/m<sup>2</sup>.

Separately, a coating liquid (11) for an ink-receiving layer was prepared by mixing 100 parts by weight of fine silicate particles (trademark: Finesseal, made by Tokuyama Soda K.K.) with 30 parts by weight of polyvinyl alcohol (trademark: PVA 117, made by Kuraray).

The coating liquid (11) was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 8 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### 10 Example 7

A spun-bonded filament nonwoven fabric was prepared by accumulating a plurality of continuous polypropylene filaments to form a web, and partially bonding the filaments by heat-pressing the web between a pair of embossing rolls at a temperature of 140°C. The filaments in the resultant nonwoven fabric had a thickness of 2.2 dtex (2.0 denier) and the nonwoven fabric had a thickness of 120 µm.

Separately, a coating liquid (12) for an undercoat layer was prepared by mixing 100 parts by weight of a polyvinyl acetate emulsion (trademark: Boncoat 2830, made by Dainihon Ink, dry solid content: 50% by weight) with 7 parts by weight of a foam stabilizer (trademark: SN Foam 200, made by Sunnopco) and foaming the mixture using a hand mixer to such an extent that the apparent volume of the coating liquid increased to 6 times the non-foamed coating liquid volume.

The foamed coating liquid had a viscosity of 27,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (12) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 12 g/m<sup>2</sup>.

The same coating liquid (11) as in Example 6 was coated on the undercoated layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 6 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### Example 8

A staple fiber nonwoven fabric was prepared by accumulating a polypropylene staple fibers to form a web, and partially bonding the staple fibers by heat-pressing the web between a pair of embossing rolls at a temperature of 140°C. The staple fibers in the resultant nonwoven fabric had a thickness of 2.2 dtex (2.0 denier) and a length of 50 mm and the nonwoven fabric had a thickness of 150 µm.

Separately, a coating liquid (13) for an undercoat layer was prepared by mixing 100 parts by weight of an SBR latex (trademark: 0629, made by Nihon Goseigomu, dry solid content: 46% by weight) with 15 parts by weight of titanium dioxide (trademark: JA-1, made by Teikoku Kako) and 15 parts by weight of a foam stabilizer (trademark: F-1, made by Dainihon Ink) and foaming the mixture using a hand mixer to such an extent that the apparent volume of the coating liquid increased to 5 times the non-foamed coating liquid volume.

The foamed coating liquid had a viscosity of 20,000 cps as measured by a Brookfield type viscometer.

The foamed coating liquid (13) was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 8 g/m<sup>2</sup>.

Separately, a coating liquid (14) for an ink-receiving layer was prepared by mixing 100 parts by weight of fine silicate particles (trademark: Tokuseal, made by Tokuyama Soda K.K.) with 20 parts by weight of an oxidized starch (trademark: Ace A, made by Oji Cone Starch), and 15 parts by weight of a polyacrylic resin emulsion (trademark: Boncoat 3226, made by Dainihon Ink).

The coating liquid (14) was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 11 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### 50 Example 9

A staple fiber-carded nonwoven fabric was prepared by accumulating core-in-sheath type composite staple fibers each consisting of a polypropylene core and a polyethylene sheath to form a web, and partially bonding the filaments by heat-pressing the web between a pair of smooth rolls at a temperature of 140°C by melting the polyethylene sheaths. The staple fibers in the resultant nonwoven fabric had a thickness of 2.0 dtex (1.8 denier) and the nonwoven fabric had a thickness of 300 µm.

The same foamed coating liquid (10) as in Example 6 was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 20 g/m<sup>2</sup>.

The same coating liquid (11) as in Example 6 was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 18 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

#### 5     Example 10

A staple fiber nonwoven fabric was prepared, by a wet nonwoven fabric-forming method, from a blend of 100 parts by weight of polypropylene staple fibers and 10 parts by weight of polyvinyl alcohol binder staple fibers.

10     The resultant nonwoven fabric had a thickness of 250  $\mu$ m.

The same foamed coating liquid (10) as in Example 6 was coated on a surface of the nonwoven fabric by using a Meyer bar coater and dried. The resultant foamed undercoat layer had a dry solid weight of 15 g/m<sup>2</sup>.

Then, the same coating liquid (14) as in Example 8 was coated on the undercoat layer surface by using a Meyer bar coater and dried to form a non-foamed ink-receiving layer having a dry solid weight of 15 g/m<sup>2</sup>.

15     An ink jet recording sheet was obtained.

#### Example 11

A viscose rayon plain weave fabric having a thickness of 200  $\mu$ m was employed as a substrate sheet.

20     The same foamed coating liquid (12) as in Example 7 was coated on a surface of the woven fabric by using a Meyer bar coater to form a foamed undercoat layer having a dry weight of 10 g/m<sup>2</sup>.

Then, the same coating liquid (14) as in Example 8 was coated on the undercoat layer surface by using a Meyer bar coater to form a non-foamed ink-receiving layer having a dry weight of 5 g/m<sup>2</sup>.

An ink jet recording sheet was obtained.

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#### Comparative Example 4

An ink jet recording sheet was produced by the same procedures as in Example 6 with the following exceptions.

30     The undercoat was omitted.

The ink-receiving layer had a dry weight of 25 g/m<sup>2</sup>.

#### Comparative Example 5

35     An ink jet recording sheet was produced by the same procedures as in Example 7 except that the nonwoven fabric was replaced by a synthetic paper sheet (trademark: Yupo FPG 60, made by Oji Yuka Goseishi, thickness: 60  $\mu$ m) and the foamed undercoat layer was omitted.

The same tests as in Example 1 were applied to the ink jet recording sheets of Examples 6 to 11 and Comparative Examples 4 and 5.

40     The test results are shown in Table 2.

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Table 2

Exemple No.	Item	Resistance to permeation of coating liquid	Color brightness	Ink absorption	Dot-reproducibility	Tear strength (g)		Water resistance
						Longitudinal	Transversal	
Example	6	3	3	3	3	700	520	3
	7	3	3	3	3	150	370	3
	8	3	3	3	3	160	240	3
	9	3	3	3	3	350	280	3
	10	3	3	3	3	300	300	3
	11	3	3	3	3	1400	1400	3
Comparative Example	4	1	3	3	3	700	520	3
	5	3	3	2	2	18	7	3

### Claims

1. An ink jet recording sheet comprising:
  - a substrate sheet;
  - an undercoat layer formed on the substrate sheet and comprising a foamed resin material; and
  - an ink-receiving layer formed on the foamed undercoat layer and comprising a mixture of an ink-receiving resin material and a pigment.
2. The ink jet recording sheet as claimed in claim 1, wherein the substrate sheet comprises a member selected from the group consisting of nonwoven fabrics and woven fabrics.
3. The ink jet recording sheet as claimed in claim 2, wherein the nonwoven fabrics are selected from the group consisting of spun-bonded filament nonwoven fabrics, staple fiber-carded nonwoven fabrics, dry laid nonwoven fabrics and wet laid nonwoven fabrics.
4. The ink jet recording sheet as claimed in claim 1, wherein the substrate sheet has a basis weight of 20 to 150 g/m<sup>2</sup>.
5. The ink jet recording sheet as claimed in claim 3, wherein the filaments for the spun-bonded filament nonwoven fabrics comprise a member selected from the group consisting of polyolefin resins, polyester resins, polyacrylate resins and polyamide resins.
6. The ink jet recording sheet as claimed in claim 1, wherein the foamed resin material of the undercoat layer comprises at least one member selected from the group consisting of homopolymers and copolymers of acrylic acid esters, polymethacrylic acid esters, ethylene-vinyl acetate copolymers, styrene-butadiene copolymers, acrylonitrile-butadiene copolymers, methyl methacrylate-butadiene copolymers, polyester resins, and polyurethane resins.
7. The ink jet recording sheet as claimed in claim 1, wherein the undercoat layer further comprises a pigment comprising at least one member selected from the group consisting of calcium carbonate, magnesium carbonate, magnesium hydroxide aluminum hydroxide, zinc hydroxide, zinc oxide, titanium dioxide, aluminum oxide, silicon dioxide, amorphous silica, barium sulfate, kolinite, talc, styrene polymer and copolymer resins and acrylic acid ester polymer and copolymer resins.
8. The ink jet recording sheet as claimed in claim 1, wherein the undercoat layer is one formed by foaming a coating liquid containing resin material and coating the foamed coating liquid onto a surface of the substrate sheet.

9. The ink jet recording sheet as claimed in claim 8, wherein the coating liquid for the undercoat layer further comprises a foam stabilizer.
10. The ink jet recording sheet as claimed in claim 8, wherein the foamed coating liquid has a viscosity of 4000 to 300,000 cps, as measured by Brookfield type viscometer.
11. The ink jet recording sheet as claimed in claim 1, wherein the undercoat layer has a dry solid weight of 3 to 50 g/m<sup>2</sup>.
12. The ink jet recording sheet as claimed in claim 1, wherein the ink-receiving resin material of the ink-receiving layer comprises at least one member selected from the group consisting of polyvinyl alcohol resins, polyvinyl alcohol derivatives, proteins, starch, starch derivatives, conjugated diene copolymers, acrylic acid ester polymer and copolymers, methacrylic acid ester polymer and copolymers, vinyl compound polymers and copolymers, functional group-modified compounds of the above-mentioned polymers and copolymers, melamine-formaldehyde resins, urea-formaldehyde resins, polyacrylamide resins, polyurethane resins, unsaturated polyester resins, polybutyral resins, and alkyd resins.
13. The ink jet recording sheet as claimed in claim 1, wherein the pigment is amorphous silica.
14. The ink jet recording sheet as claimed in claim 13, wherein the amorphous silica content is 50 to 90% by weight based on the total dry weight of the uppercoat layer.
15. The ink jet recording sheet as claimed in claim 1, wherein the ink-receiving layer has a dry solid weight of 3 to 30 g/m<sup>2</sup>.
16. The ink jet recording sheet as claimed in claim 1, wherein the undercoat layer is one formed by blowing air into an aqueous coating liquid containing a resin material during mechanical agitation of the aqueous coating liquid to foam it; and coating the resultant foamed aqueous coating liquid onto the substrate sheet.
17. The ink jet recording sheet as claimed in claim 16, wherein the blowing of air causes the apparent volume of the aqueous coating liquid to increase to 2.0 to 20.0 times.
18. The ink jet recording sheet as claimed in claim 16, wherein the foamed aqueous coating liquid has a viscosity of 3,000 to 200,000 cps as determined by a Brookfield type viscometer.
19. The ink jet recording sheet as claimed in claim 1, wherein the ink-receiving layer comprises a resin material selected from cationic group-containing polymeric compounds and carboxylic group-containing polymeric compounds and a white pigment comprising an amorphous silica.
20. The ink jet recording sheet as claimed in claim 1, wherein the substrate sheet is selected from nonwoven fabrics in which a plurality of continuous filaments are accumulated and partially fuse-bonded to each other, nonwoven fabrics in which plurality of staple fibers are opened and accumulated by a carding machine and the opened staple fibers are thermally bonded to each other; and nonwoven fabrics in which a plurality of fibers are formed into a sheet and entangled with each other by a high pressure hydro-entanglement method.



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# EUROPEAN SEARCH REPORT

Application Number  
EP 94 30 9732

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DATABASE WPI Section Ch, Week 9302, Derwent Publications Ltd., London, GB; Class A97, AN 93-014894 & JP-A-4 344 284 (OJI PAPER CO) 30 November 1992 * abstract *	1-3,5,6, 8,20	B41M5/00 B41M1/26
Y	---	12-15,19	
Y	EP-A-0 379 964 (JUJO PAPER CO. LTD.) * the whole document * ---	12-15,19	
X	US-A-5 001 106 (EGASHIRA ET AL.) * column 2, line 65 - column 3, line 13 * * column 10, line 62 - column 11, line 7 * ---	1,6,12	
P,X	DATABASE WPI Section Ch, Week 9442, Derwent Publications Ltd., London, GB; Class A32, AN 94-337872 & JP-A-6 262 712 (OJI PAPER CO) 20 September 1994 * abstract * -----	1-3,5,6, 8,9,12	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B41M
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 21 April 1995	Examiner Bernardo Noriega, F
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